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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 :
G02B 27/22, G03B 35/00
G02B 27/02

A1

(11) International Publication Number: WO 89/ 09423

(43) International Publication Date: 5 October 1989 (05.10.89)

(21) International Application Number: PCT/IT89/00009

(22) International Filing Date: 23 February 1989 (23.02.89)

(31) Priority Application Numbers: 20053 A/88
23069 A/88

(32) Priority Dates: 31 March 1988 (31.03.88)
23 December 1988 (23.12.88)

(33) Priority Country: IT

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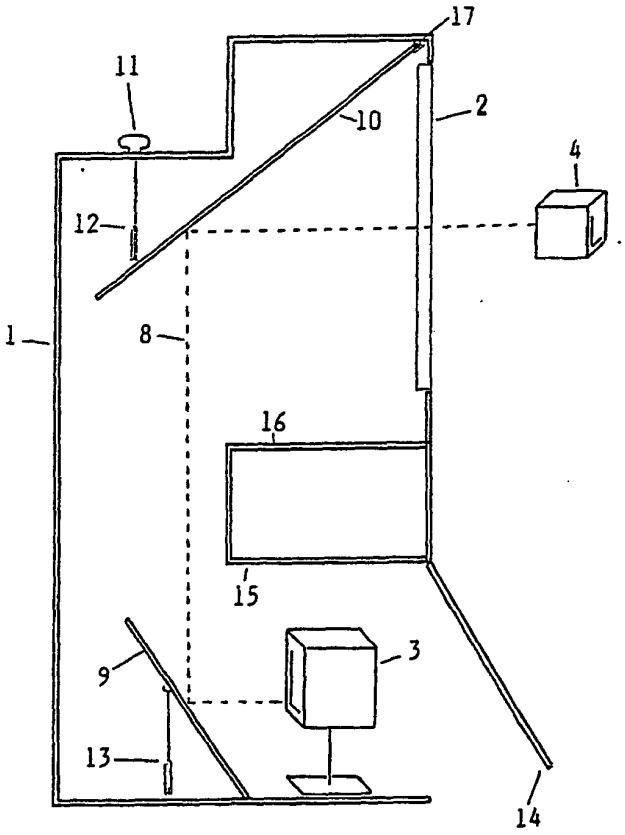
(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, KR, LU (European patent), MC, NL (European patent), SE (European patent), SU, US.

Published
With international search report.

(54) Title: THREE-DIMENSIONAL IMAGE PROJECTOR

(57) Abstract

The projector comprises: a chamber designed to contain the object (3) to be projected, having dark, opaque, non-reflecting walls; a Fresnel lens (2) occupying an aperture in one wall of the chamber, said lens (2) having a diameter larger than the maximum dimension of the object (3) to be projected, an optical axis (8) projected in the direction of the object and a focal distance smaller than the length of the optical circuit between the object and the lens; one or more light sources located in the chamber to illuminate the object and suitably screened from the lens so as not to project diffused light on the latter.



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"THREE-DIMENSIONAL IMAGE PROJECTOR"

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The present invention concerns a three-dimensional image projector and more precisely an optical device by means of which three-dimensional images can be viewed in the space in front of the projection screen.

At present, reproduction of stereoscopic images of an object is achieved by means of more or less complex systems based substantially on the use of two flat stereoscopic images (of the object itself) and of suitable devices (such as prisms, striped screens, glasses with differently polarized lenses, etc.) which consent each of the two stereoscopic images to be viewed by one eye, or on the use of holograms obtained from a two-dimensional photosensitive emulsion impressed by interference between two laser beams, one of which coming directly from the light source and the other reflected from the object.

These systems present various drawbacks, the main ones being that:

- they require sophisticated and costly techniques and/or do not allow prolonged viewing of the three-dimensional images without tiring the eyes of the viewer;
- they do not always allow the object to be viewed from different angles;
- they do not allow the immediate projection of any object;
- they do not enable the object to be viewed in its natural colours;
- they do not enable the object to be viewed in movement.

The purpose of this invention is to remedy the aforementioned drawbacks by providing a three-dimensional image projector whereby any object can be viewed in real time, in its natural colours and, if necessary, in movement, without calling for particularly costly equipment

and without tiring the eys of the viewer, who is able to gaze quite naturally at the three-dimensional image of the object projected in the space in front of th screen.

According to a first embodiment, the projector according to the invention comprises:

- a chamber designed to contain the object to be projected, having dark, opaque, non-reflecting walls;
- a Fresnel lens occupying an aperture in one wall of the chamber, said lens having a diameter larger than the overall dimensions of the object to be projected and an optical axis projected in the direction of the object and a focal distance smaller than the length of the optical circuit between the object and the lens;
- one or more light sources located in the chamber to illuminate the object and suitably screened from the lens so as not to project diffused light on the latter.

Other inventive solutions are given further on, in the claims.

The features of the invention will be more clearly evident from the following examples of non-restrictive embodiments described with reference to the accompanying drawings, in which:

Figs.1 and 2: show a first embodiment of a projector according to the invention;;

Figs.3, 4 and 5: show a second embodiment of a projector according to the invention;

Fig.6: shows an automatic system for controlling the illumination of the object to be projected;

Fig.7: shows a third embodiment of a projector according to the invention.

Figs.1 and 2 show a schematic representation of a cross-sectional view (on a horizontal and a vertical plane, respectively) of a first embodiment of a projector according to the invention, in which the following references are used to indicate the various parts:

1: substantially parallelepipedon-shaped chamber with opaque walls with a dark-coloured non-reflecting internal surface;
2: Fresnel lens;
3: object to be viewed three-dimensionally; in this specific case, it consists of a cube with an L printed on the side facing the lens;
4: real image, with three-dimensional effects, of the object 3; 5: viewer;
6: projectors for illuminating the object 3 (with light having a spectrum as similar as possible to the solar spectrum);
7: screens for protecting the projectors 6, in order to prevent diffused light from being projected onto the lens 2.

When the projectors 6 are turned off, the lens 2 is seen by the viewer as a dark screen. However, as soon as the projectors are turned on, the viewer sees, in front of the screen consisting of the lens, the (upside down) three-dimensional image of the object, in its natural colours, so as to give him the impression of standing in front of the object itself, which appears to hover in the space in front of the projector. The sensation of three-dimensionality is also confirmed when the viewer moves sideways with respect to the image of the object: in this case, in fact, the viewer becomes aware of the change in perspective which normally accompanies a change in parallax. The extent to which the viewer can move sideways (or even vertically) is, of course, limited by the field of visibility of the image which, with close approximation, can be likened to a cone with its apex in the optical centre of the lens (the angle at the top of the cone has been indicated by the reference "a" in Fig. 2).

In order to enable the projector to give satisfactory results, the lens and the object must fulfill certain dimensional requirements.

In fact, so as not to have an excessively narrow field of visibility (angle "a") it is necessary for the focal distance of the lens to be within the same order of magnitude as the diameter of the lens itself or smaller. Moreover, the object must also be placed at a given distance from the lens so that the distance between the projected image and the lens is in the same order of magnitude as the abovementioned diameter or smaller. The nearer the projected image is from the lens the wider the aforesaid field of visibility will be.

Moreover, the lens must have a larger diameter than the maximum dimension of the object. The best results are obtained with a lens having a diameter at least three times that of the aforesaid maximum dimension of the object.

A further embodiment of a projector according to the invention is schematically illustrated in Figs.3 (cross-sectional view) and 4 (frontal view), in which the parts indicated by references used previously in Figs. 1 and 2 have equivalent functions. The remaining parts are:

9 and 10: flat mirrors;

11: knob for adjusting the angle of inclination of the mirror 10;

12 and 13: screws for adjusting the angle of inclination of the mirrors 10 and 9;

14: door giving access to the compartment containing the object to be projected, which normally remains closed when the projector is in operation (in Fig. 3 the door is shown half open and in Fig. 4 wide open);

15: wall screening the object 3 from the mirror 10;

16: wall screening the mirror 9 from the lens 2.

In this embodiment the mirrors 9 and 10 perform multiple functions:

- to project an upside down image of the object 3 onto the lens 2 so that the lens 2 can project an upright three-dimensional image to the outside;

- to make the luminous rays projected from the object 3 onto the lens follow a C-shaped route (see route 8 in Fig.3), so that, with a lens of the same diameter and an optical route of the same overall length, the apparatus is more compact and less bulky than the apparatus referred to in the example in Figs. 1 and 2;
- to enable the position of the projected image to be adjusted vertically, by varying the angle of inclination of the mirror 10 by means of the knob 11.

With regard to the latter function of the mirrors it can be seen that when the mirror 10 (which is hinged by 17) is rotated downwards, the image 4 also shifts in the same direction.

It can also be seen that when the two mirrors 9 and 10 are perpendicular to each other, then any vertical plane of the object 3 is projected out of the lens 2 still as a vertical plane. Conversely, when the mirrors form an angle of (90° + B), then the vertical plane of the object 3 printed with the letter L is projected out of the lens with an inclination on the vertical having an amplitude of 2·B.

Consequently, if it is required to adjust the vertical position of the image of the object so that it automatically respects the verticality of the planes, it is necessary to improve the system for adjusting the inclination of the mirrors, as shown in the schematic example of Fig.5. According to this sketch the mirrors are secured on one side to the hinges 17 and 18 and on the other to one end of the rods 19 and 20. The other end of the rods, which can be lengthened or shortened telescopically, is secured to the hinge 22. Said hinge can slide along the circular guide 23, whose centre of curvature coincides with the midpoint of the segment having its ends in 17 and 18, so that each swinging of the mirror 10, caused by turning the knob 11, corresponds to a swinging of the mirror 9, which ensures the perpendicularity of the two mirrors.

The previously described apparatus (as well as that of Figs.1 and 2) can operate in environments subject to any lighting conditions whatsoever, either natural or artificial. However, in order to have a clear view of the image the illumination of the object 3 must always be adapted to suit the degree of luminosity of the environment. This can be achieved by providing projectors with lamps with adjustable brightness, which can be adjusted by means of a special control circuit operated by hand (by means of an external control knob, not shown in the figure), or operated by an automatic control system. In this latter case, it will be sufficient to provide (in a per se known way) an input control circuit 24, activated by a signal from a photoconductive cell 21 located on the front panel of the projector in the vicinity of the Fresnel lens (see Fig.4 and Fig.6).

Fig.7 shows a cross sectional view of a third embodiment of a projector according to the invention, in which reference 27 indicates a convex spherical mirror, 25 indicates a semitransparent flat mirror tilted at 45° and 26 indicates a transparent or semitransparent screen. In this apparatus the semitransparent mirror 25 performs several functions, such as that of:

- limiting the overall dimensions of the apparatus while keeping the route of the optical rays from the object to the spherical mirror the same;
- enabling the flat mirror to reflect the object and then project the rays onto the spherical mirror;
- enabling (thanks to its semitransparency) the image created by the spherical mirror to be projected to the outside, upright;
- preventing the viewer outside the apparatus from seeing in.

The apparatuses referred to in the examples shown in Figs.3, 5 and 7 are also subjected to identical or similar dimensional conditions as those described for the lens and the object of Fig. 2.

In addition to the aforsaid conditions, the three-dimensional image produced by the apparatuses according to the invention is, of course, also subject to the optical laws which govern the formation of images in the lenses and in the mirrors, whereby a ray which strikes the lens or the spherical mirror in a direction parallel to the optical axis emerges from the lens or the mirror in the direction of focus, etc.

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C L A I M S

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1.

Three-dimensional image projector, characterized by the fact of comprising:

- a chamber designed to contain the object to be projected, having dark, opaque, non-reflecting walls;
- a Fresnel lens occupying an aperture in one wall of the chamber, said lens having a diameter larger than the maximum dimension of the object to be projected, an optical axis projected in the direction of the object and a focal distance smaller than the length of the optical circuit between the object and the lens;
- one or more light sources located in the chamber to illuminate the object and suitably screened from the lens so as not to project diffused light on the latter.

2.

Projector as claimed in Claim 1, characterized by the fact that the focal distance of the lens is of the same order of magnitude as the diameter of the lens itself or smaller, and that the length of the optical circuit between the object to be projected and the lens is such that the image projected by the lens is situated at a distance from the latter in the same order of magnitude as the diameter of the lens or smaller.

3.

Projector as claimed in any of the previous claims, characterized by the fact that the diameter of the lens is more than three times the maximum dimension of the object to be projected.

4.

Projector as claimed in any of the previous claims, characterized by the presence of an optical circuit consisting of a set of flat mirrors positioned so as to projec the optical axis of the lens towards the object.

5.

Projector as claimed in Claim 4, characterized by the presence of one or more optical screens for the purpose of preventing the direct projection of light rays from the illuminated object onto the Fresnel lens.

6.

Projector as claimed in the previous claim, characterized by the fact that the mirrors are of an even number.

7.

Projector as claimed in Claim 5, characterized by the fact that one or more of the mirrors is movable, inasmuch as its inclination with respect to the incident optical axis can be varied.

8.

Projector as claimed in Claim 7, characterized by the fact that the mirrors are two in number and are secured to each other by means designed to ensure their reciprocal perpendicularity in every possible position.

9.

Three-dimensional image projector, characterized by the combined presence of:

- a chamber designed to contain the object to be projected, having dark, opaque, non-reflecting walls;
  an aperture in one wall of the chamber having dimensions larger than the dimensions of the object to be projected;
- a concave spherical mirror, having a diameter larger than the maximum dimension of the object to be projected, located inside the chamber in front of the aforesaid aperture;
- a flat semitransparent mirror positioned between the concave mirror and the aperture and oriented so as to reflect the optical axis of the spherical mirror in the direction of the object;
- an object to be projected, positioned so that its distance from the concave mirror, measured along the route of the optical axis, is greater than the focal distance.

10.

Projector as claimed in Claim 9, characterized by the presence of another semitransparent mirror positioned over the aforesaid aperture.

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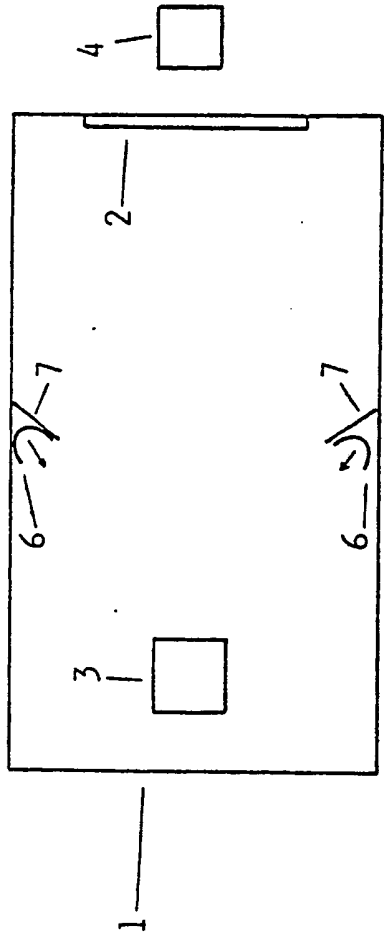

FIG.1

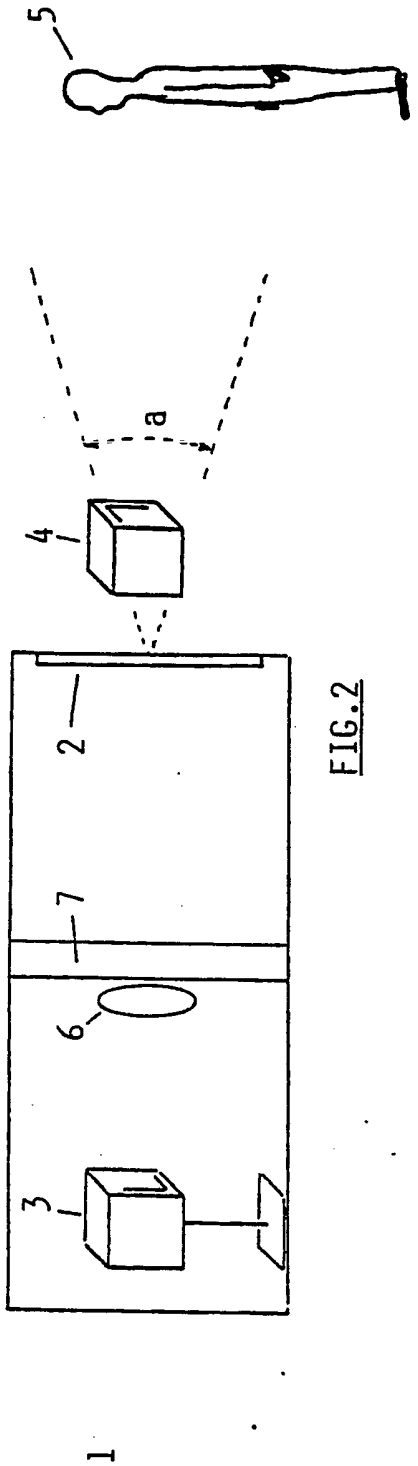

FIG.2

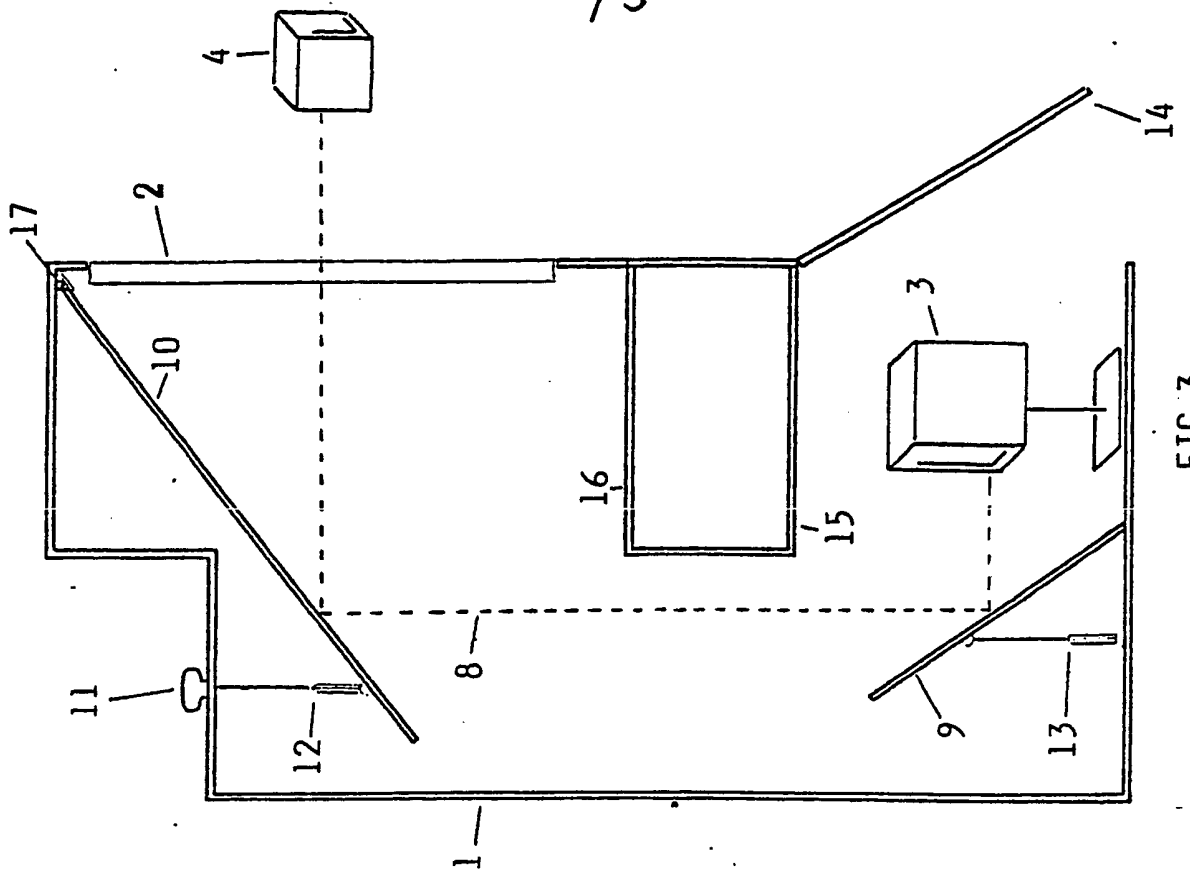

FIG.3

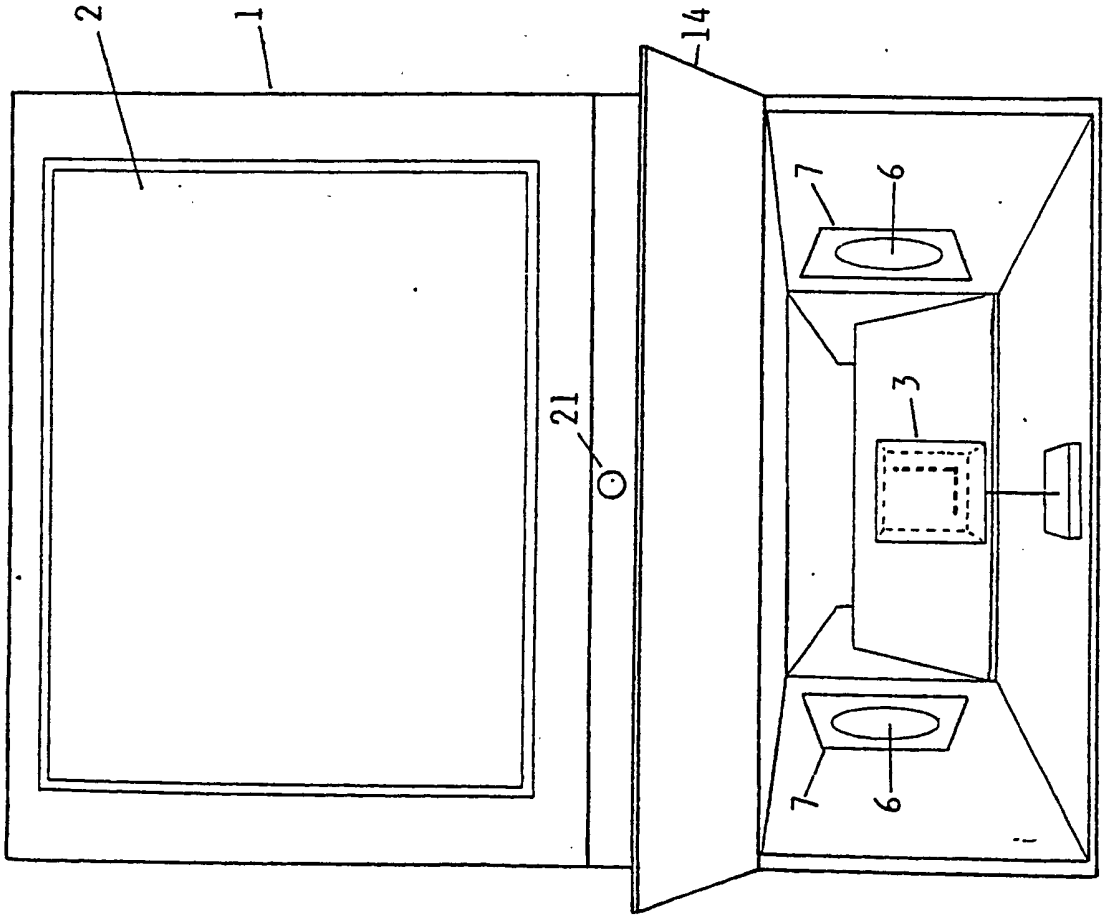

FIG.4

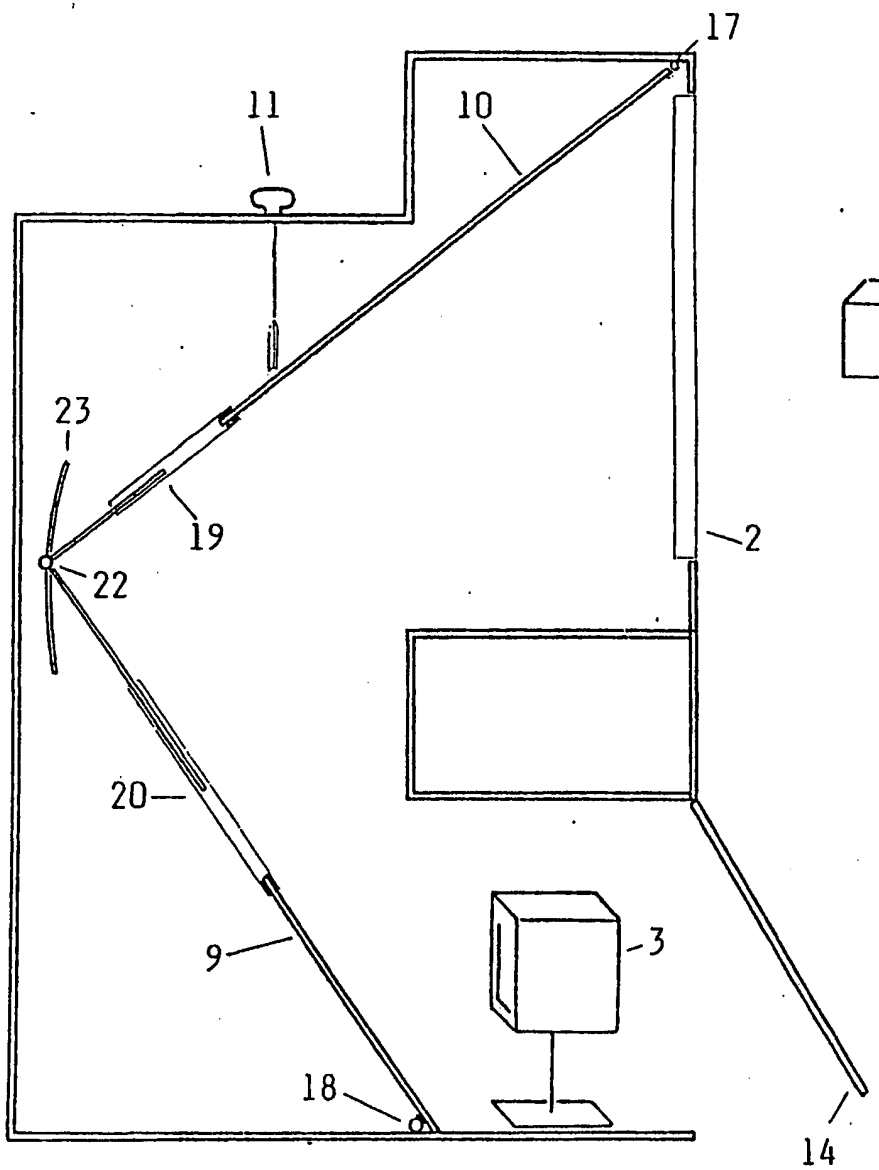

FIG.5

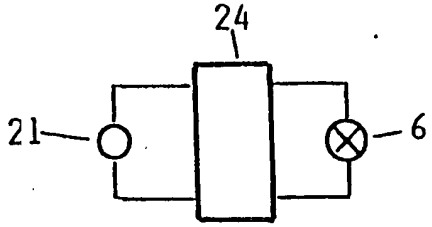

FIG.6

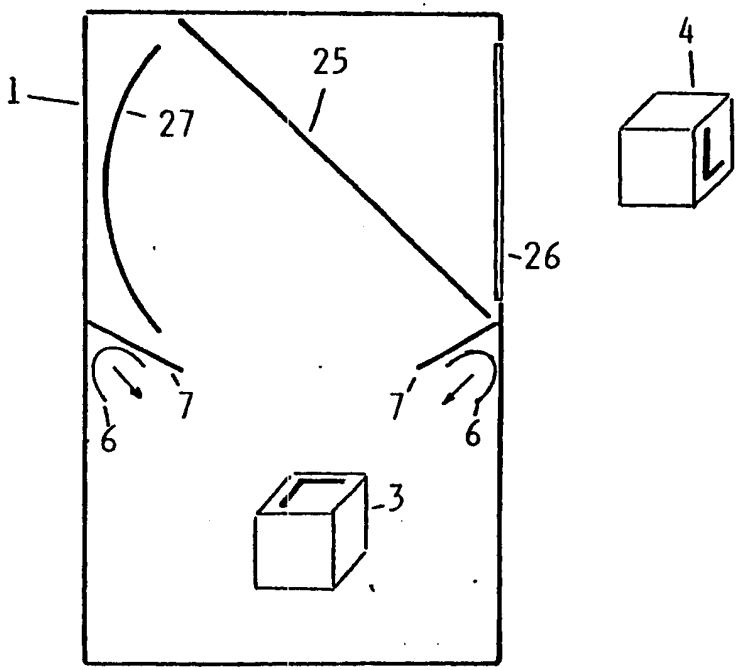

FIG.7

INTERNATIONAL SEARCH REPORT

International Application No PCT/IT 89/00009

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: G 02 B 27/22; G 03 B 35/00; G 02 B 27/02

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[4]	G 02 B; G 03 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 4671625 (NOBLE) 9 June 1987 see column 1, line 32 - column 2, line 8; column 2, line 61 - column 3, line 12; column 3, line 65 - column 4, line 7; column 5, lines 30-40; figures 1,3	1-4,6
Y	--	9
Y	GB, A, 675549 (COPELAND) 9 July 1952 see page 1, lines 53-82; figure 1	9
	--	
X	DE, A, 2612566 (RUSTERHOLZ et al.) 23 June 1977 see claims 1,2,6,8; figure 1	1,5
	--	
A	DE, A, 3013959 (SAUL) 22 October 1981 see claims 1-3; page 8, lines 22-27; figure 1	8,9
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	./.	

* Special categories of cited documents: [10]

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"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
6th June 1989	07. 07. 89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 4120563 (STEFANOU) 17 October 1978 see abstract; figure 1 --	7
A	US, A, 4623223 (KEMPF) 18 November 1986 see abstract; figure 1 --	9
A	GB, A, 2155651 (NIGHTINGALE) 25 September 1985 see claims; figure 1	1

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO. IT 8900009
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A- 4671625	09-06-87	JP-A- 60059317	05-04-85
GB-A- 675549		None	
DE-A- 2612566	23-06-77	CH-A- 612769	15-08-79
DE-A- 3013959	22-10-81	None	
US-A- 4120563	17-10-78	None	
US-A- 4623223	18-11-86	None	
GB-A- 2155651	25-09-85	None	